

used it may be dissolved together with the semiconductor (see column 9, lines 36-37), both the binder and organic semiconductor are dissolved (see column 10, lines 2-3), and in the examples, a mixture of semiconductor and binder were dissolved in a solvent (see column 23, lines 39-40).

On the other hand, Minakata teaches that the purpose of using substituted pentacenes was to increase the crystallinity of the semiconductor film (see column 6, lines 32-39 and 48-51, and column 7, lines 1-4 teaching that the preparation methods allows that "crystal growth can be controlled ... to form an organic semiconductor thin film having high crystallinity. The resultant organic semiconductor thin film has superior characteristics as a semiconductor due to high crystallinity. ... in the organic semiconductor thin film of the present invention, formed crystals tend to have polyacene molecules with their long axis perpendicular to the face of the substrate). See also column 25, lines 6-10 teaching that

The organic semiconductor thin films of the present invention have superior semiconductor characteristics since these thin films are almost defect-free and have high crystallinity.

The invention of Minakata is based on the idea that pentacene in its pure, crystalline state is useful in the semiconductor layer, and said crystallinity is responsible for the superior characteristics of the product.

Consequently, according to the teaching of Minakata the dissolving of the pentacene in the layer in any way (e.g. by mixing it with a binder) would be totally undesired and directly contrary to the teachings recited above, since this is expected by one of ordinary skill in the art to disrupt the crystalline structure of the pentacene.

As such, one of ordinary skill in the art would not find it desirable to combine the teachings of these two references. For this reason, the rejection should not be maintained.

As explained in the application on page 1, line 35 to page 2, line 13, when the substituted pentacene is mixed with an organic binder, it is effectively "diluted" by the binder. Diluting the organic semiconductor by mixing it with binders disrupts the molecular order in the semiconducting layer. Hence, following the teaching of Minakata, the person skilled in the art would rather expect a reduction of the charge mobility as Minakata teaches the importance of maintaining the crystallinity of the semiconductor. Also, diluting an organic semiconductor in the channel of an OFET for example is particularly problematic, as any

disruption of the orbital overlap between molecules in the immediate vicinity of the gate insulator (the first few molecular layers) is expected to reduce mobility. Electrons or holes are then forced to extend their path into the bulk of the organic semiconductor, which is undesirable. See, e.g., Minakata teaching the formation of films that are almost defect-free and crystalline, see column 25, line 8.

In view of the teachings of Brown and/or Minakata, it was therefore totally surprising and unexpected for the skilled person that mixing a substituted pentacene with a binder can yield a transistor device with significantly increased charge carrier mobility.

Additionally, the present application provides unexpected results over the cited references.

Example 17 of Minakata is believed to be the closest prior art example. This example provides a crystallized 6,13-bis(triisopropylsilylethynyl)pentacene film with the triisopropylsilylethynyl group oriented perpendicular to the substrate surface and achieved a carrier mobility of  $0.12 \text{ cm}^2/\text{V}\cdot\text{s}$ . Compare this to example 12 of the present application where the same compound 6,13-bis(triisopropylsilylethynyl)pentacene was in combination with a binder p- $\alpha$ MS and provided a mobility of  $0.433 (\pm 0.19) \text{ cm}^2/\text{V}\cdot\text{s}$ . The improvement is more than  $3 \frac{1}{2}$  in mobility value, which is completely unexpected considering Minakata teaches the importance of maintaining the crystallinity of the pentacene in the film.

Applicants also provide example 13 (comparative) which again tests the 6,13-bis(triisopropylsilylethynyl)pentacene without a binder and achieves a mobility of  $0.14 (\pm 0.14) \text{ cm}^2/\text{V}\cdot\text{s}$ , which is consistent with the findings of Minakata.

Additionally, unexpected results are provided over the examples of Brown also. See, e.g., the table in Brown on columns 25 and 26. Here, 5 binders (see key to identity of binders on column 23) are tested with various semiconductor compounds (which are not pentacenes). All mobility values with these binders and also the other binders were in the range of  $10^{-4}$  to  $10^{-5} \text{ cm}^2/\text{V}\cdot\text{s}$  (see also claim 7 in Brown). Binders 2, 3 and 4 are also exemplified in the present application with pentacenes. See binders P-4MS, PS-co- $\alpha$ MS, and P- $\alpha$ MS respectively (see key to identity of binders on page 55). The results with these same binders in combination with a pentacene yielded results in the  $0.16$  to  $1.1 \text{ cm}^2/\text{V}\cdot\text{s}$  range (see results in the tables on pages 52 to 54 of the specification), which are several fold higher than the results obtained with these same binders and other semiconductor compounds by Brown. In

view of the consistency of the results with various semiconductor compounds by Brown, it is highly unexpected to one of ordinary skill in the art that another semiconductor compound, i.e., in the present case polyacene, would yield such significantly higher mobility values.

Accordingly, this additional reason also supports the patentability of the present invention.

Additionally, applicants provide the following further comments.

In the semiconducting films of the present application (like in examples 12 and 14) the substituted pentacene compounds are not completely dissolved, but are phase-separated as small crystalline domains in the amorphous binder. In contrast, in the examples of US 7,061,010 (Minakata, Asahi Glass), as well as in the comparative examples 13 and 15 of this application, the pentacene forms a pure crystalline film as expected in view of the teachings of Minakata.

The pentacene/binder films of the present application have several advantages, like the following:

- Processing and film formation during device manufacture is much easier because there is no need to have controlled crystallization, and the pentacene/binder composite can more easily be coated and transformed into a thin film, e.g. because the amorphous binder polymers have much better rheology than the crystalline pentacene. Also, the use of a binder allows a much broader choice of suitable solvents. This makes the pentacene/binder system e.g. also highly suitable for printing processes.
- The uniformity of the semiconducting properties and of the device performance is better (i.e. the charge mobility values show less variation in different areas of the film). See Table 4 in the present application, where examples 12 and 14 (with the pentacene/binder film) show a much smaller relative standard deviation of the charge mobility ( $0.433 \pm 0.19$  and  $1.1 \pm 0.4$ , which is about 40-50% of the mean value), which confirms the higher film uniformity. In contrast, the comparative examples 13 and 15 (with a pure crystalline pentacene film) show a much larger relative standard deviation ( $0.14 \pm 0.14$  and  $0.11 \pm 0.11$  which is 100% of the mean value).
- Nevertheless, the mobility in our pentacene/binder film is similar or

even higher than in a pure pentacene film, as shown in examples 12 and 14 and comparative examples 13 and 15.

- Another advantage (not mentioned so far) is that by diluting the pentacene with the binder it is possible to save costs (compared to a pure pentacene film) because the binder material is much cheaper than the pentacene.

These advantages could not be expected from the cited prior art (Minakata, US 7,061,010 and Brown et al., US 7,095,044), since Minakata does not suggest to dilute the pentacene with a binder and Brown does not suggest to use the substituted pentacenes of formula I of the present claims.

Moreover, Minakata reports that a film of 2,3-bis(triisopropylsilylethynyl)pentacene of his example 15 (which is clearly described as being crystalline) has a mobility of only 0.08  $\text{cm}^2/\text{V}\cdot\text{s}$ , which is lower than in most of the examples of the present application. The skilled person could not expect that by diluting the substituted pentacene of Minakata with a binder, it would be possible to even increase the mobility, and in addition to achieve further advantages like an increased uniformity. This was also not suggested by Brown, because Brown does not show a direct comparison between semiconducting films with and without binder. In particular, Brown does not suggest a possible increase of the mobility (and a much lower standard deviation of the mobility) when using a binder.

Reconsideration is respectfully requested.

### **Claim Objection**

Claim 15 is objected to because the value of the variable “n” is allegedly not clear. The last line of claim 15 recites “wherein  $n=10.7$ ,” which appears clear in that the value of “n” is equal to “10.7.”

The Commissioner is hereby authorized to charge any fees associated with this response or credit any overpayment to Deposit Account No. 13-3402.

Respectfully submitted,

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